

# St Croix County Hydrogeology

St Croix County groundwater and surface water  
committee meeting

March 14, 2017

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Wisconsin Water Science Center



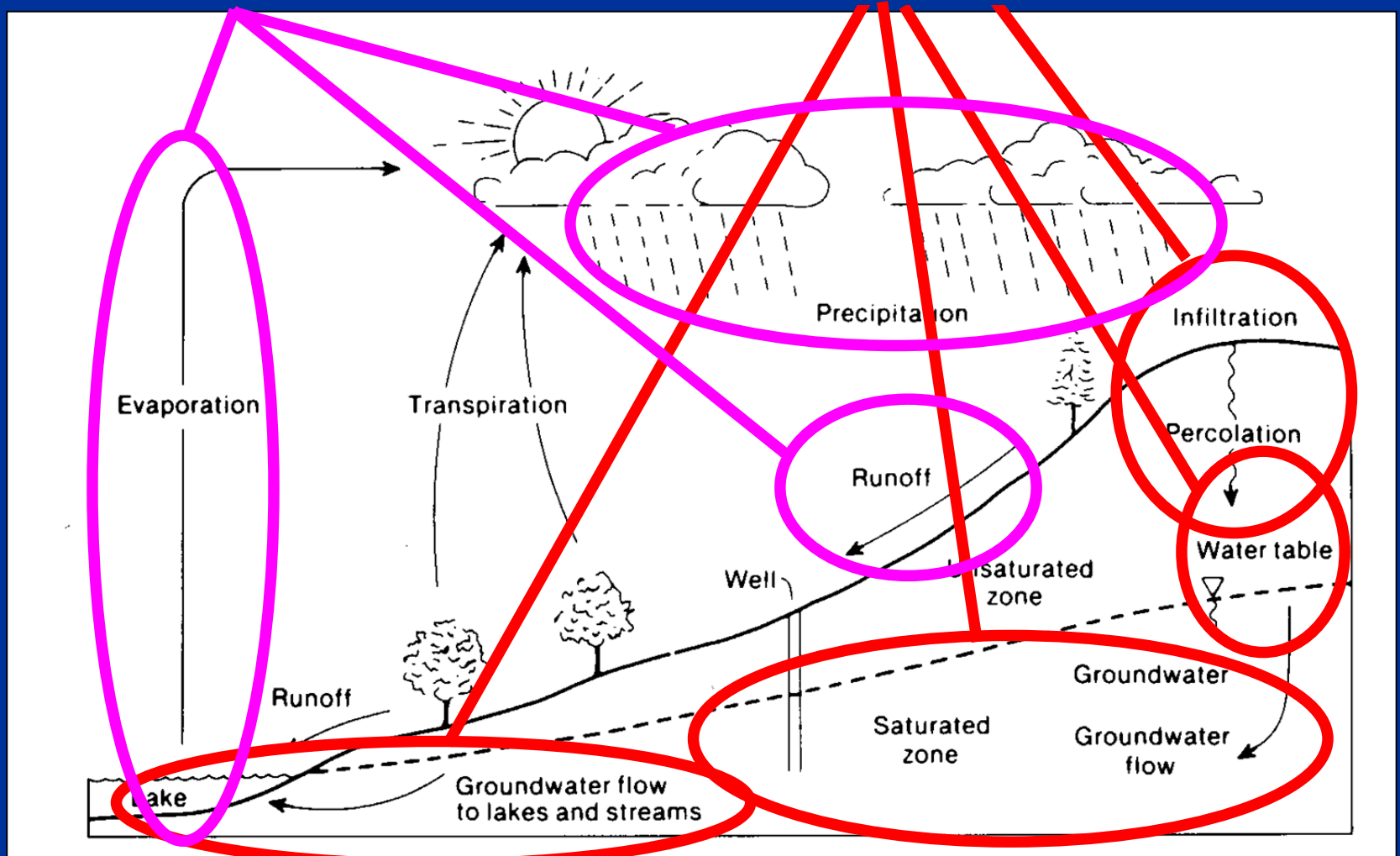
# Some Ground Water Basics:

- Ground water and surface water are interconnected (57 – 91% of annual streamflow is from ground water in St. Croix County)

# All water on earth is part of the water cycle

Surface processes

Ground-water flow



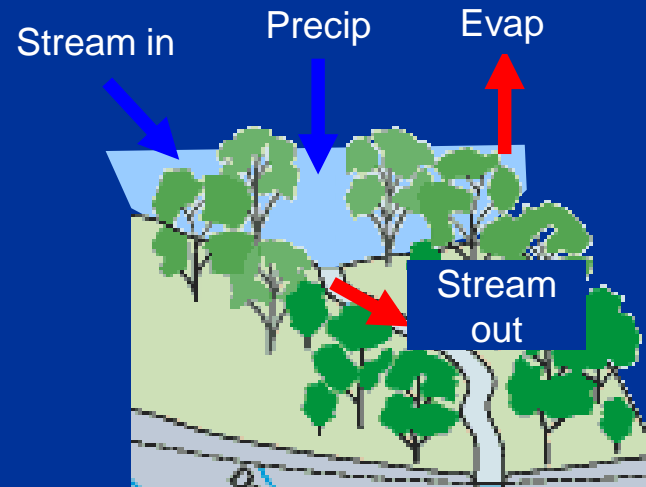
# Some Ground Water Basics:

- Ground water and surface water are interconnected (57 – 91% of annual streamflow is from ground water in St. Croix County)
- Travel (transport) times vary, depending on the flow path and type of rock

# Water moves, but often at a different timeframe than we are used to

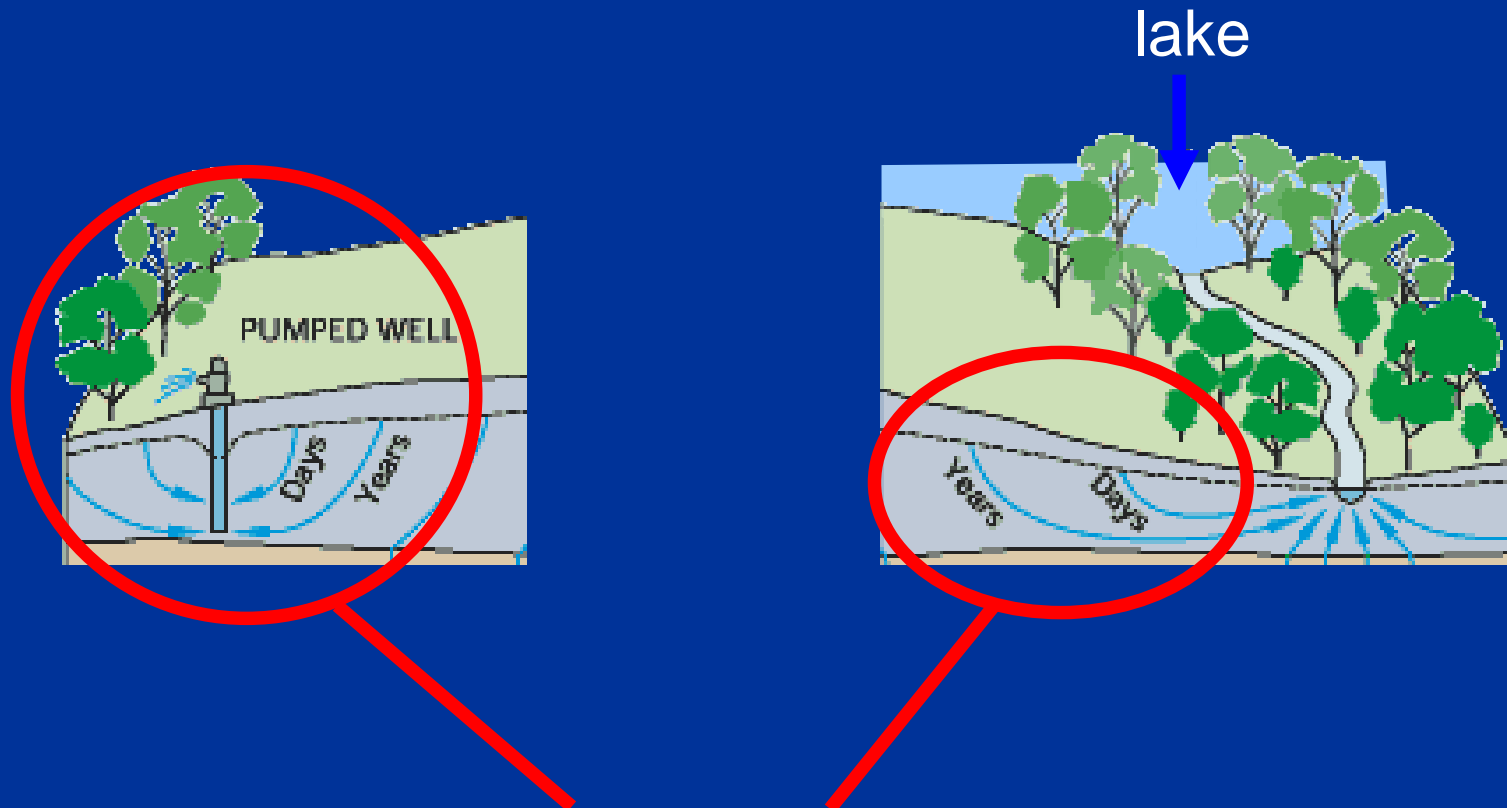
In a stream, often can see water moving

In a lake, often cannot see water moving except at inflowing and outflowing streams



But, water added to lakes replaces water leaving lakes. Total replacement takes on the order of tens of years.

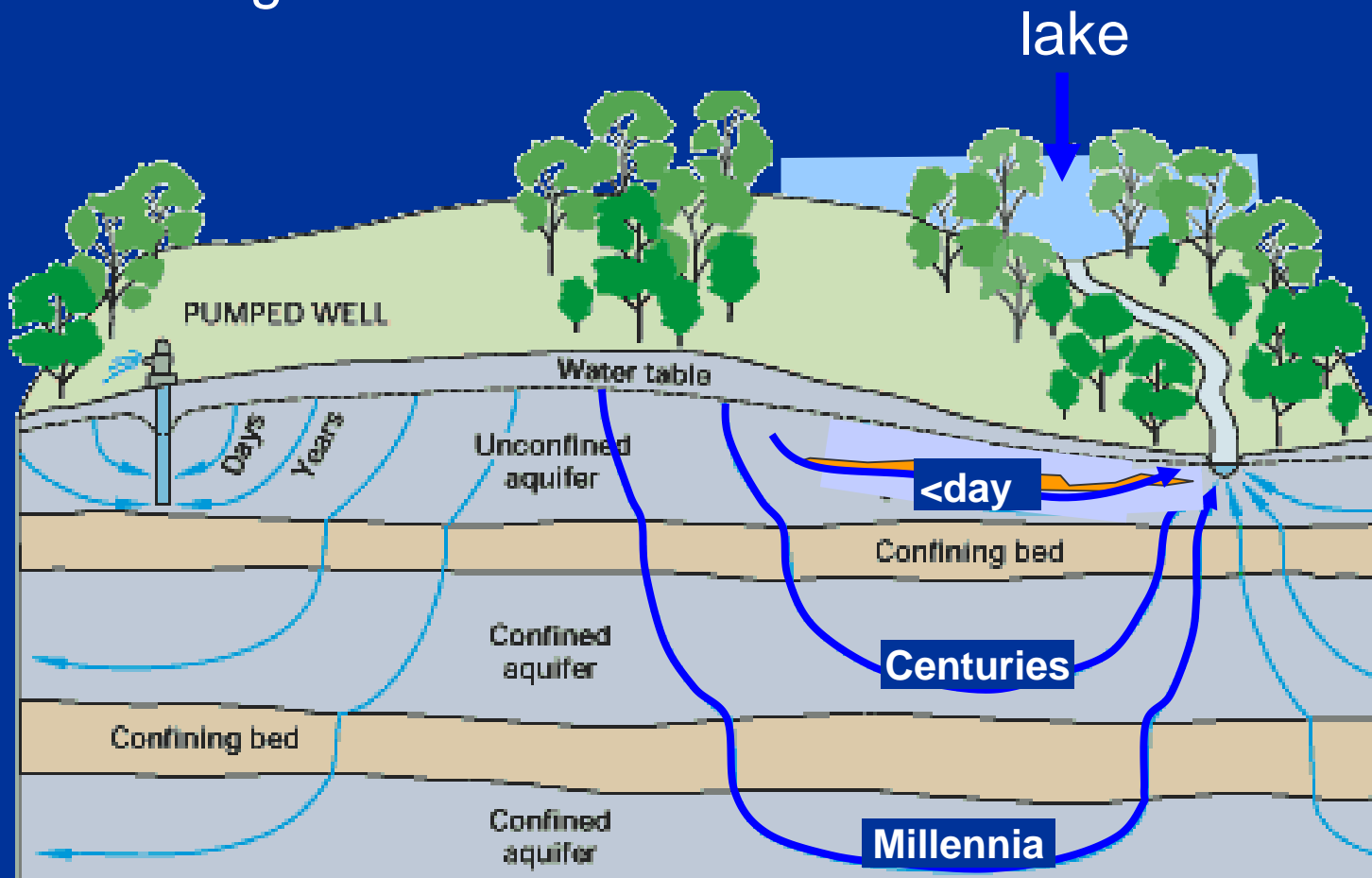
# Water moves, but often at a different timeframe than we are used to



Water traveling in the groundwater system can be of similar time scales

# Water moves, but often at a different timeframe than we are used to

but not all groundwater!

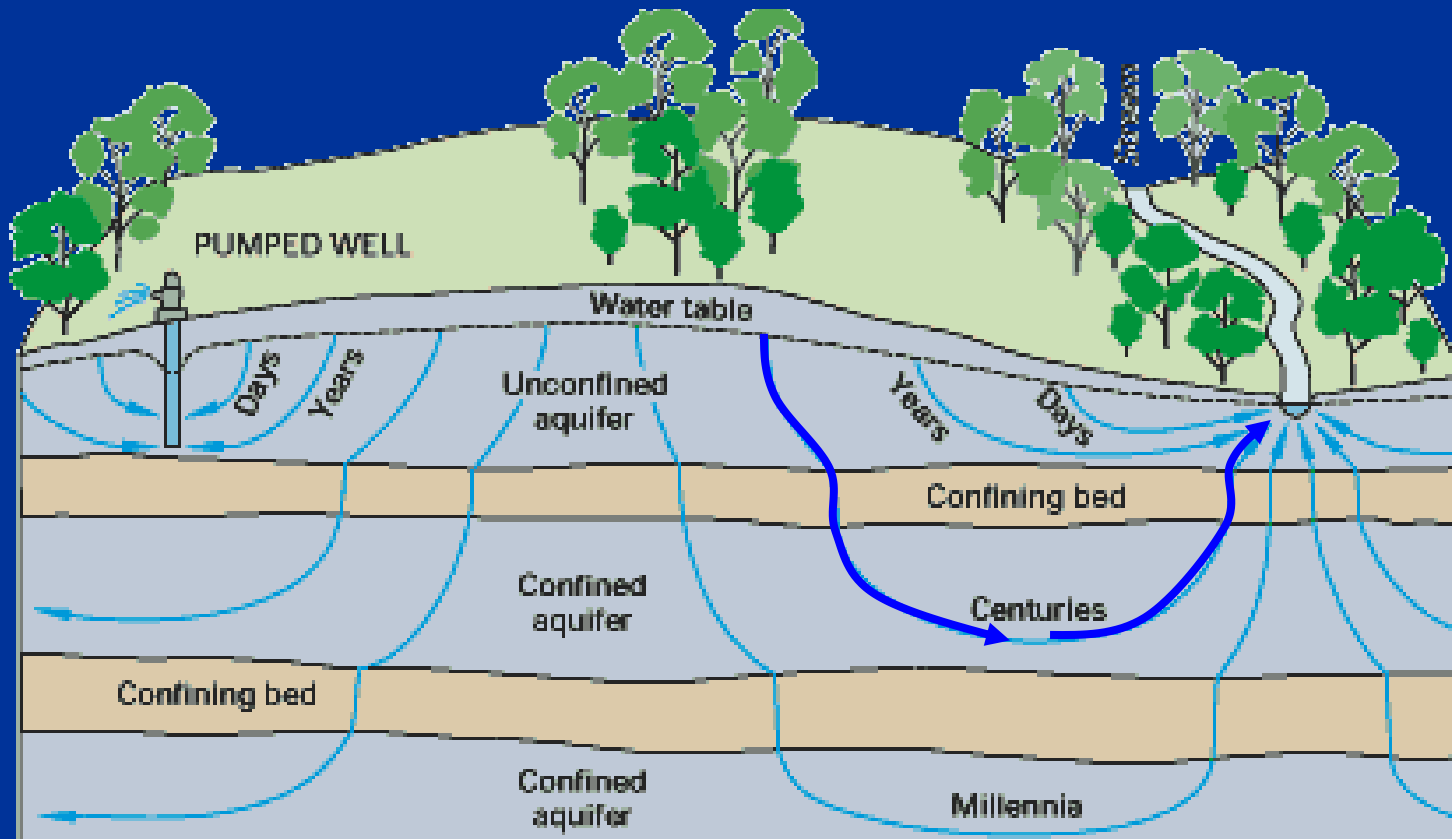


# Some Ground Water Basics:

- Ground water and surface water are interconnected (57 – 91% of annual streamflow is from ground water in St. Croix County)
- Travel (transport) times vary, depending on the flow path and type of rock
- Plumber's rule: ground water flows down-gradient (from high to low hydrostatic pressure)



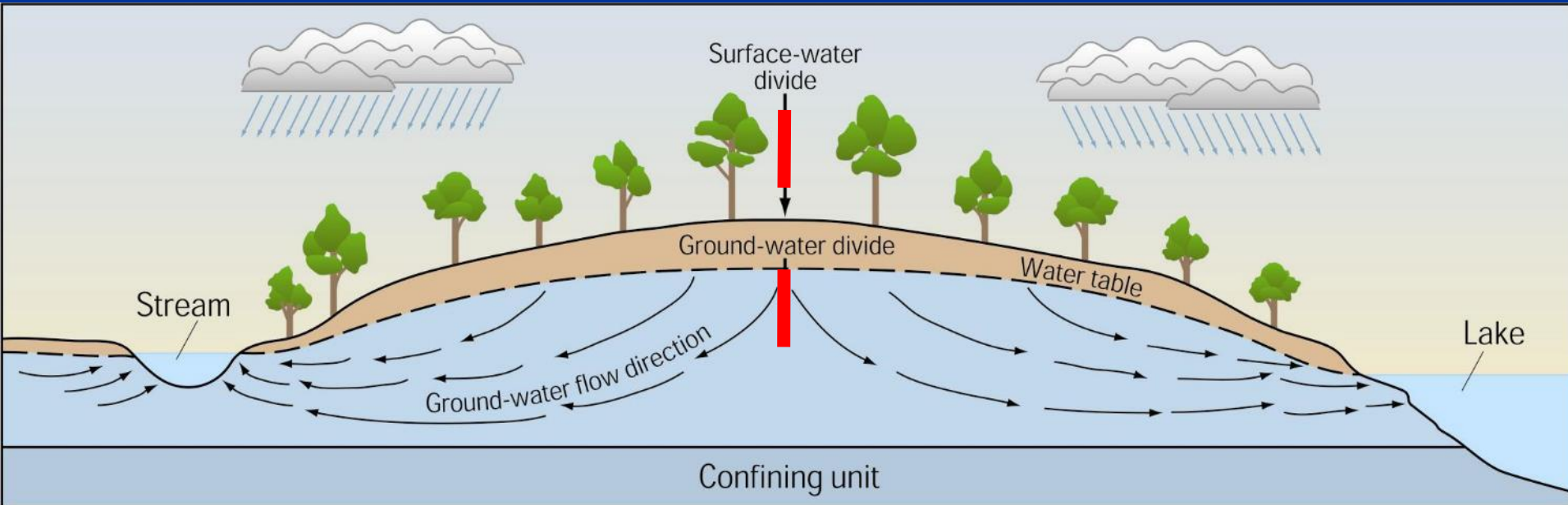
# Ground water flows down-gradient



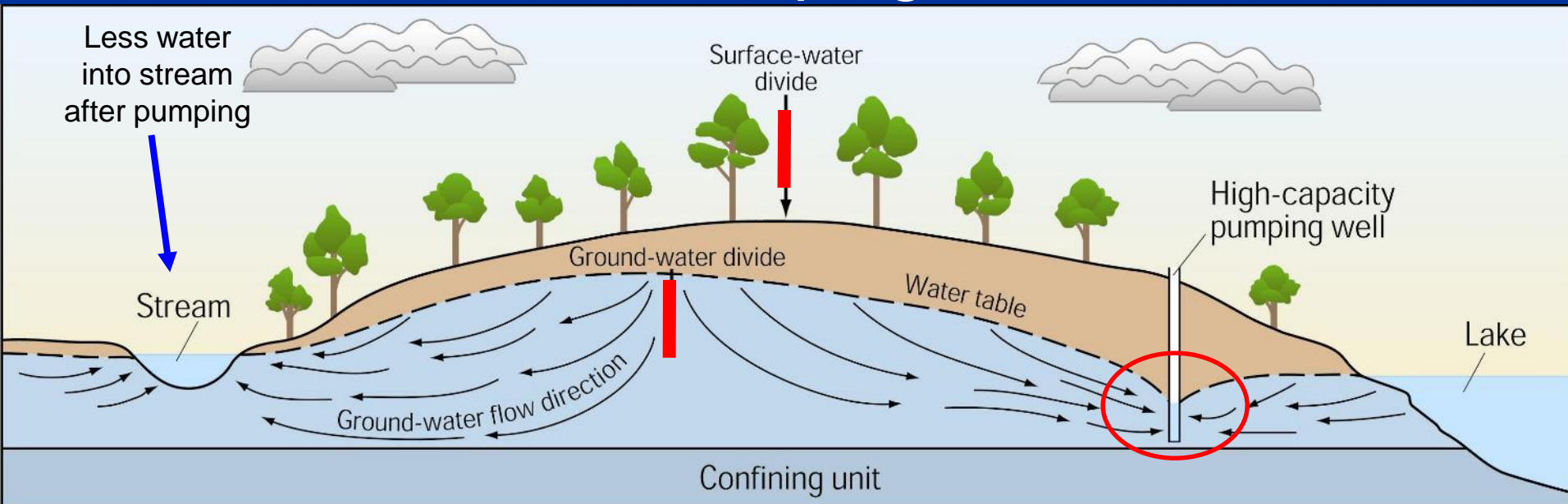
# Some Ground Water Basics:

- Ground water and surface water are interconnected (57 – 91% of annual streamflow is from ground water in St. Croix County)
- Travel (transport) times vary, depending on the flow path and type of rock
- Plumber's rule: ground water flows down-gradient (responds to hydrostatic pressure)
- Capture – withdrawal in one location reduces quantity available for nearby resources (water has to come from somewhere)

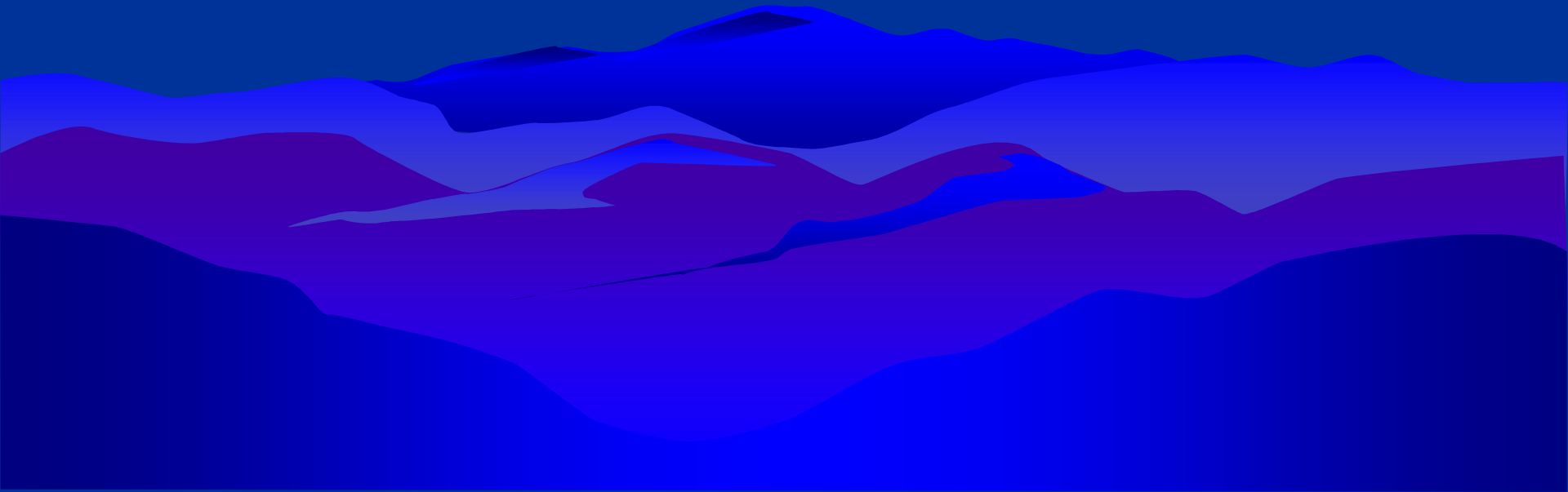
# Natural conditions



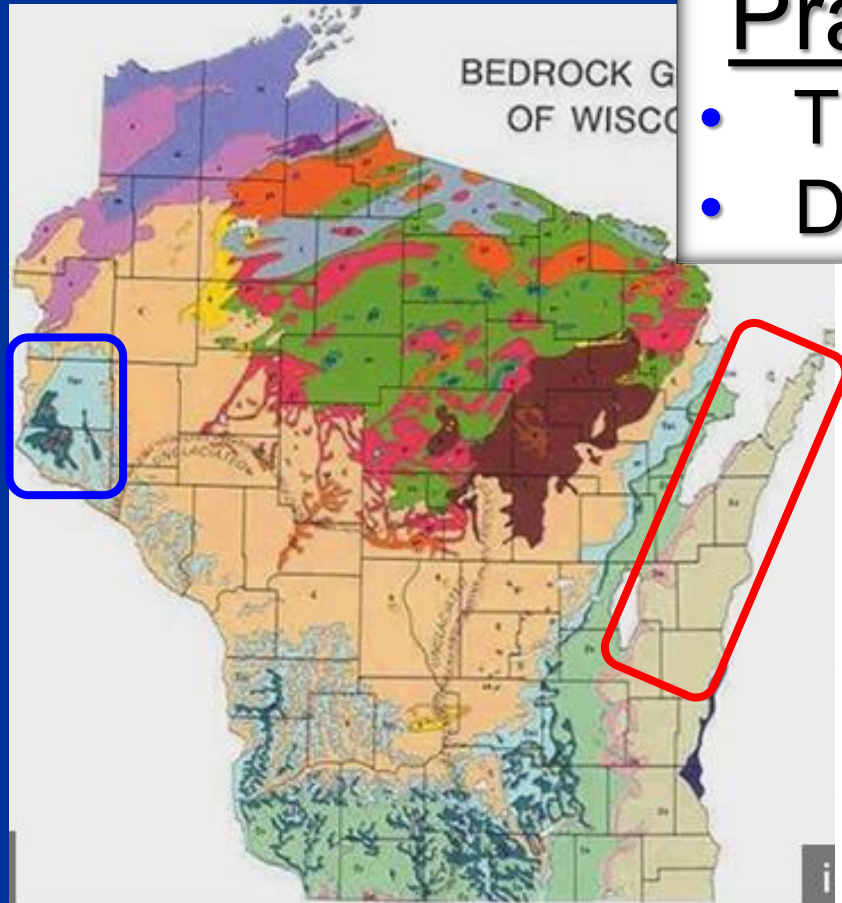
# Pumping



Hydrogeologic concepts for  
St Croix  
and  
Kewanee Counties

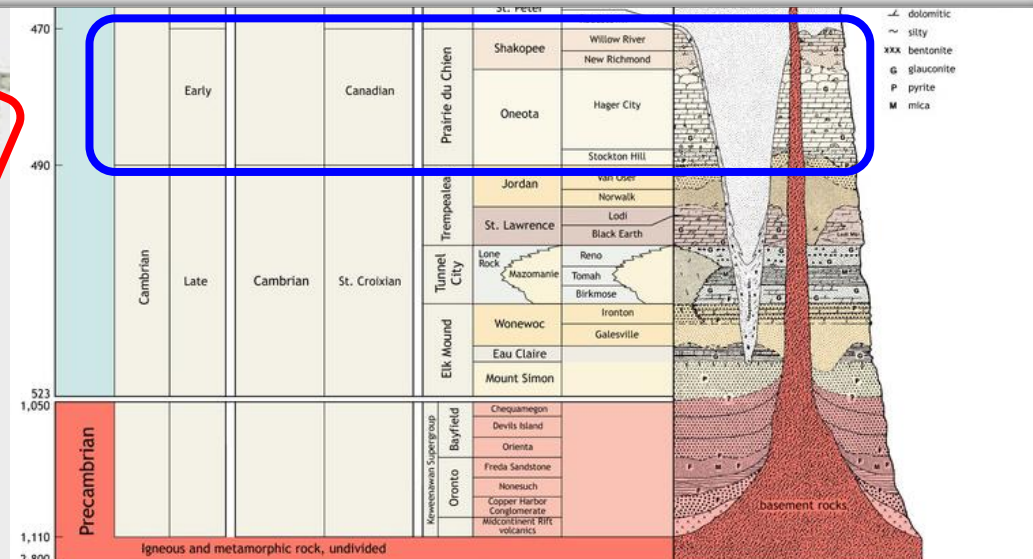
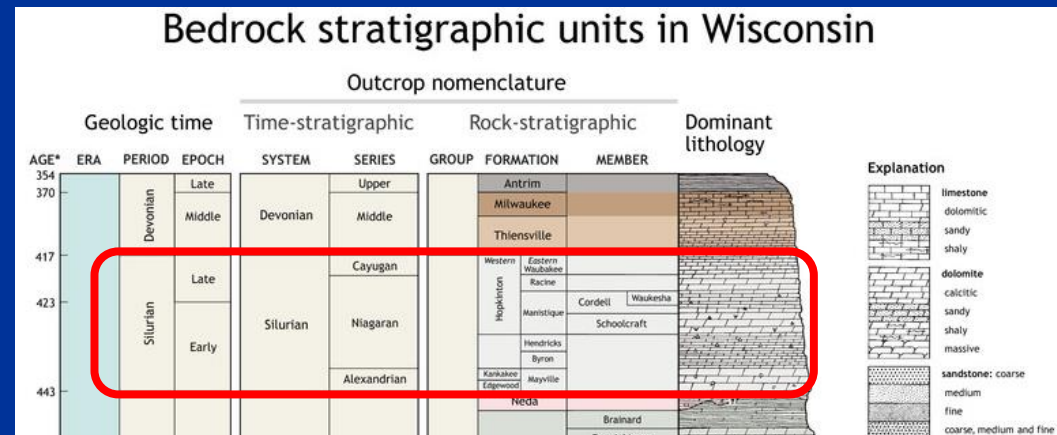


# Wisconsin Bedrock



## Prairie du Chien Dolomite

- Thicker soils (>15ft common)
- Dissolution enlarged fractures



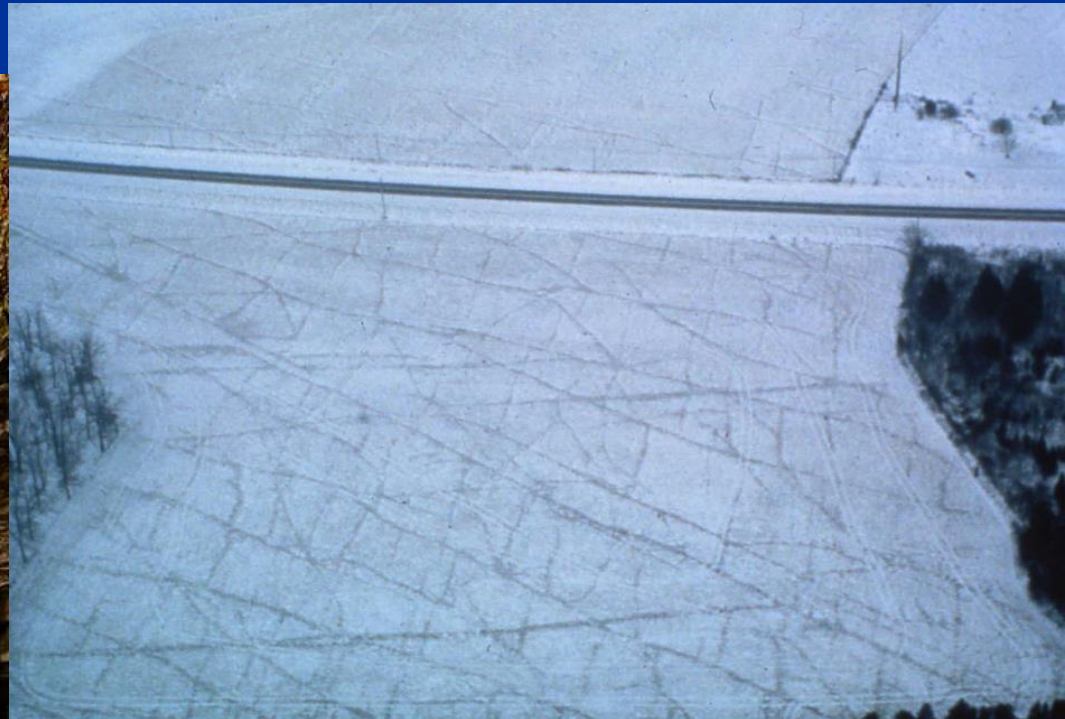
\* Absolute age dates in million years are based on the Geological Society of America Geologic Time Scale, 1998.

Modified from Ostrum, M.E., 1968. Paleozoic Stratigraphic Nomenclature for Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 8.

Wisconsin Geological and Natural History Survey Open-File Report 2006-06  
This material represents work performed by staff of the Wisconsin Geological and Natural History Survey or colleagues and is released to the open files in the interest of making the information readily available. This material has not been edited or reviewed for conformity with Wisconsin Geological and Natural History Survey standards and nomenclature.

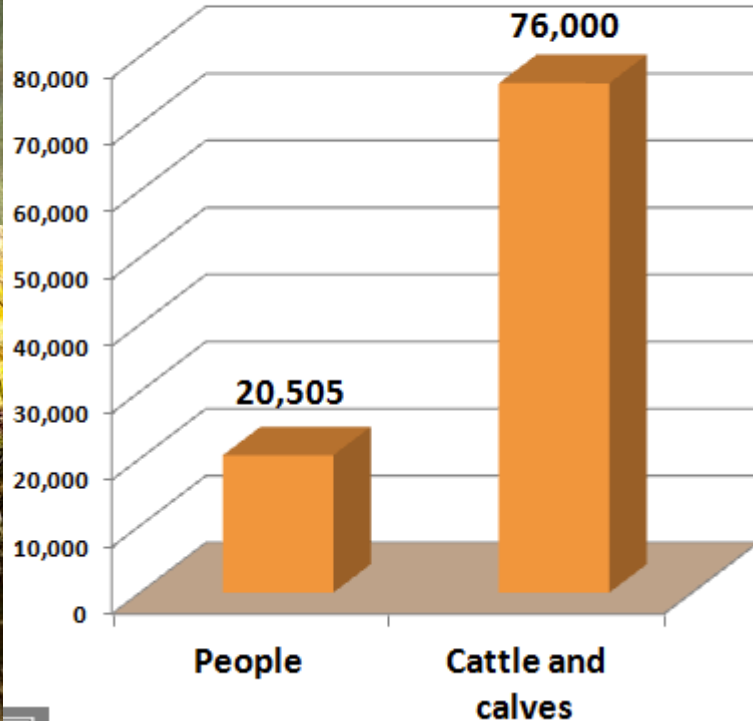


# Kewanee County – Silurian Dolomite



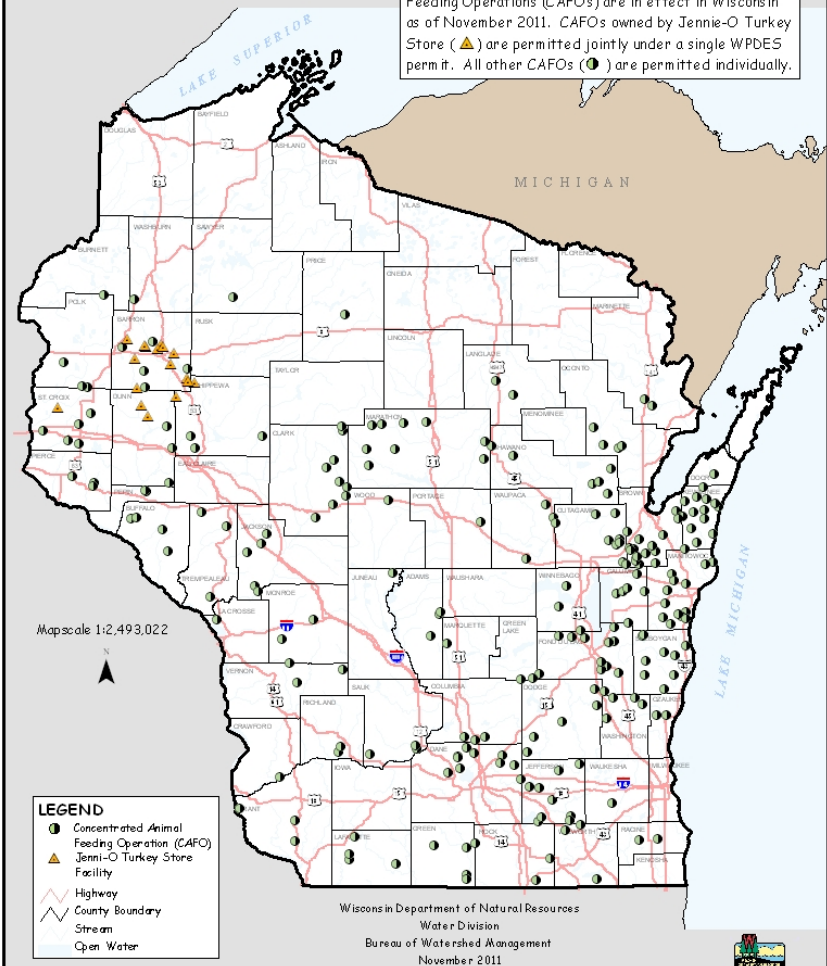
# Kewanee County – Silurian Dolomite

**People vs. cattle and calves in  
Kewanee County**



**Wisconsin's WPDES Permitted  
Concentrated Animal Feeding Operations**

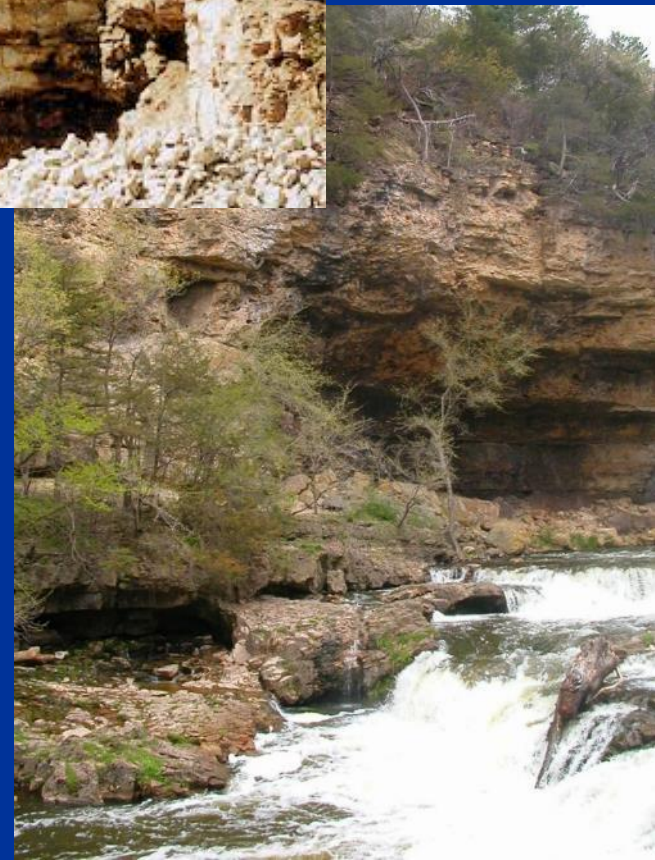
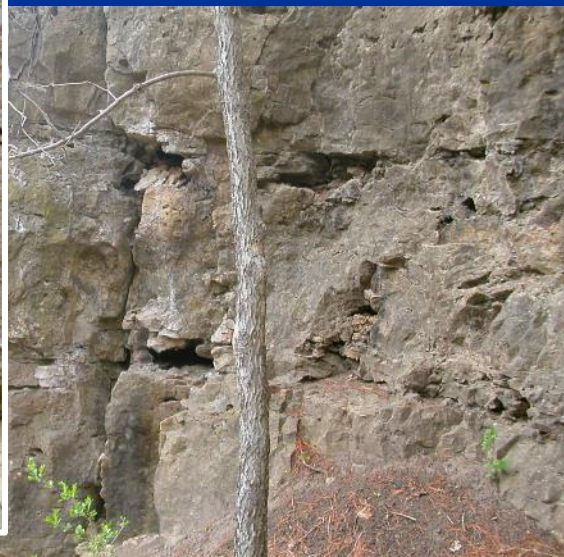
A total of 233 WPDES permits for Concentrated Animal Feeding Operations (CAFOs) are in effect in Wisconsin as of November 2011. CAFOs owned by Jennie-O Turkey Store (▲) are permitted jointly under a single WPDES permit. All other CAFOs (●) are permitted individually.





# St. Croix County – Prairie du Chien

WABASHA COUNTY, MN  
Credit: Tony Runkel, MGS



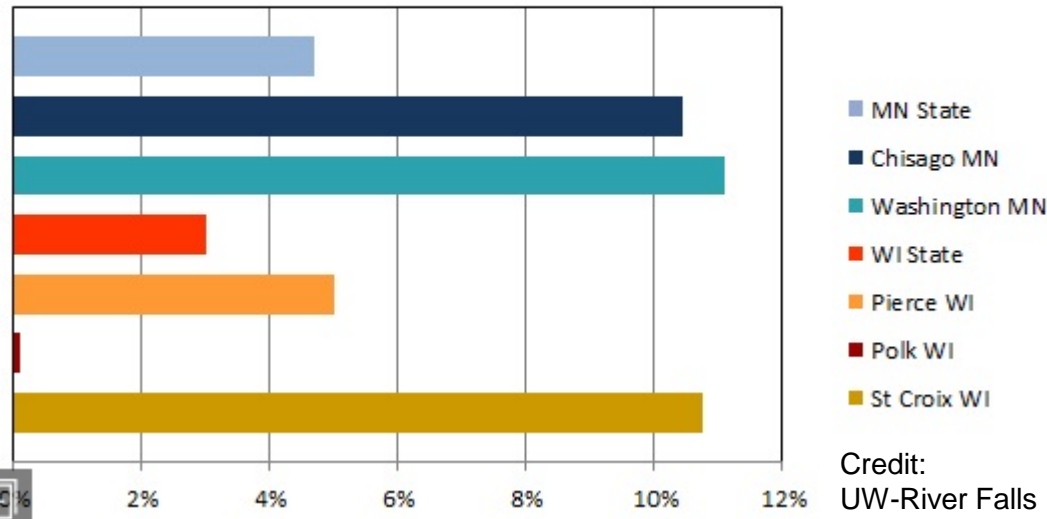


# St. Croix County – Prairie du Chien

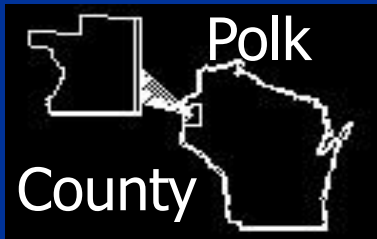
Sink hole

Glacial topography?

Population Change  
2005-2012



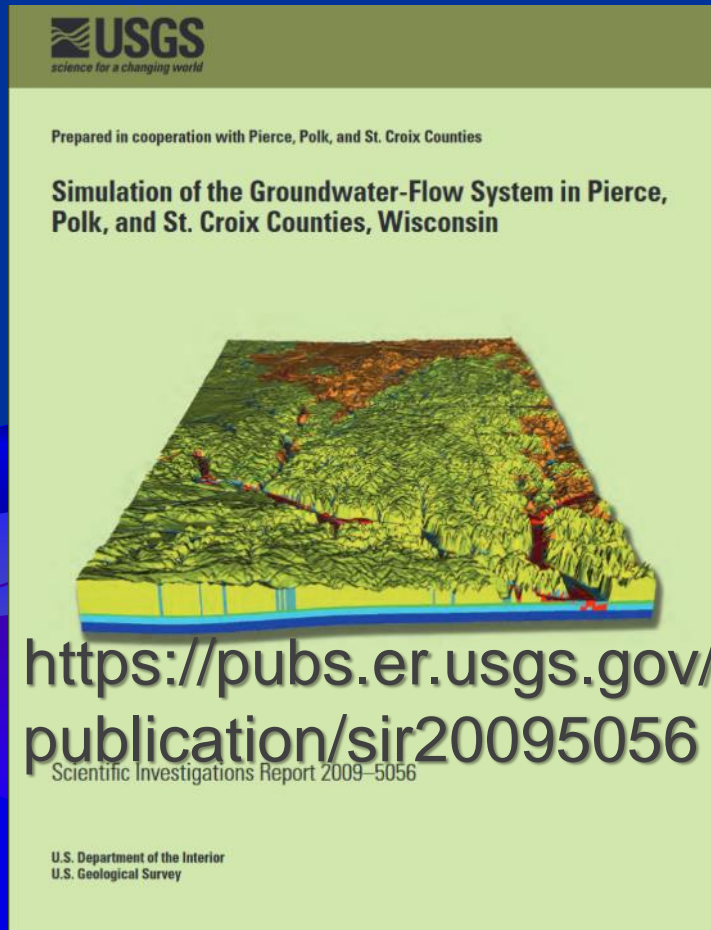
# Simulation of Regional Groundwater Flow in Pierce, Polk and St. Croix Counties, Wisconsin



St. Croix  
County



Pierce County



With assistance from:





# The Tri-county Project: Objectives

- Improve understanding of ground-water flow in Pierce, Polk and St. Croix counties
- Simulate regional surface-water/ground-water interactions, and ground-water-flow patterns using computer models
- Provide a quantitative framework for testing possible future change
- Demonstrate the utility of targeted (inset) ground-water flow modeling in each county

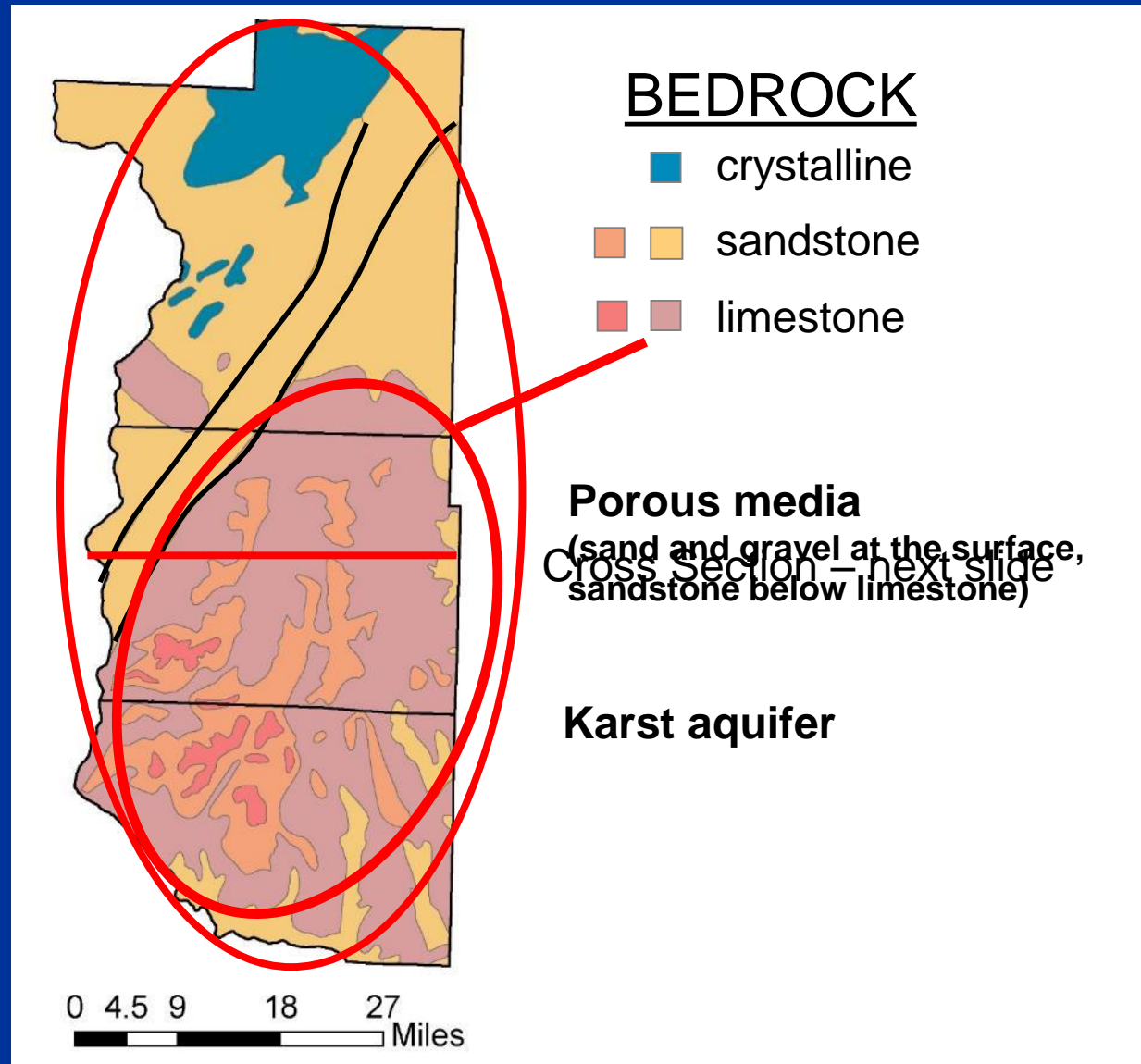


# How Models Work:

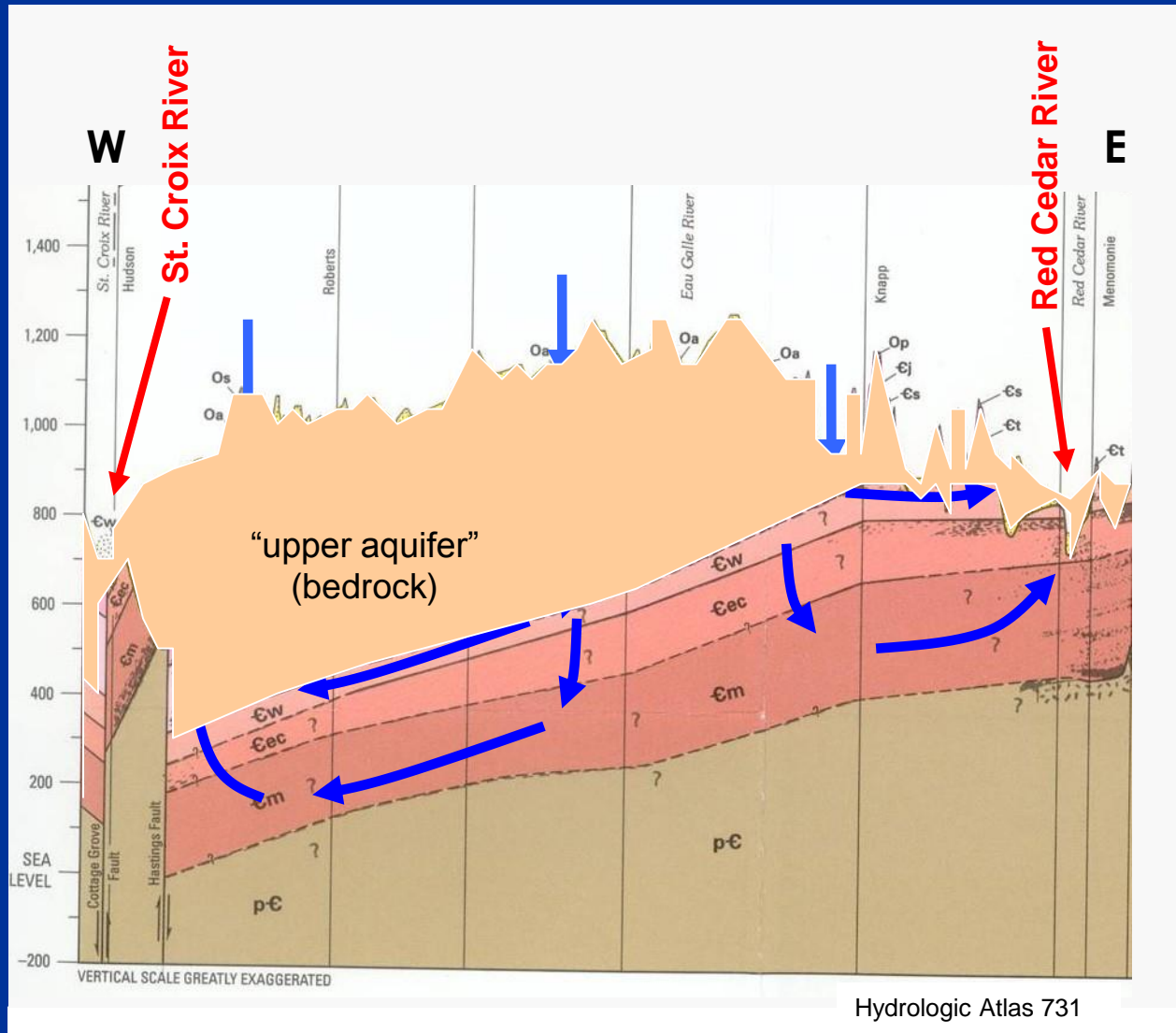
- Golden Rule: “water can not be created or destroyed”
- Plumber’s Rule: “water flows down-gradient”
- Numerical equations representing real world entered into the computer (*geologic properties, surface-water bodies, pumping*)
- Calibrate (*data requirements can be large - “results are only as good as the data”*)



# Two kinds of aquifers

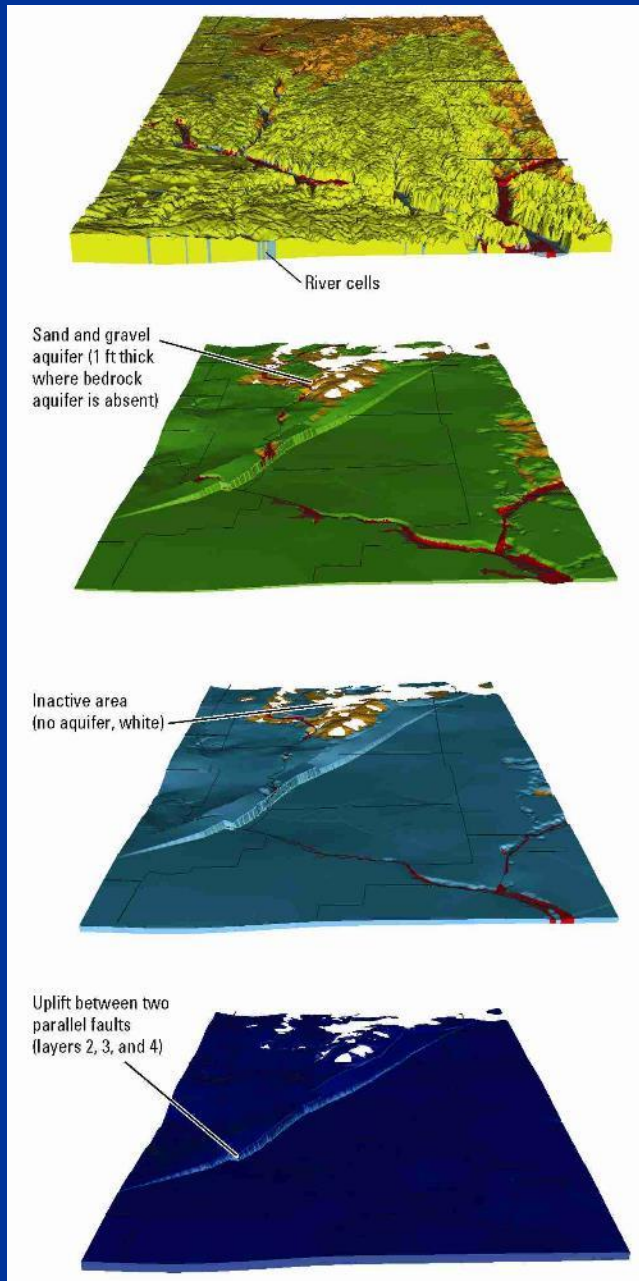


# Conceptual Model



# Model Development

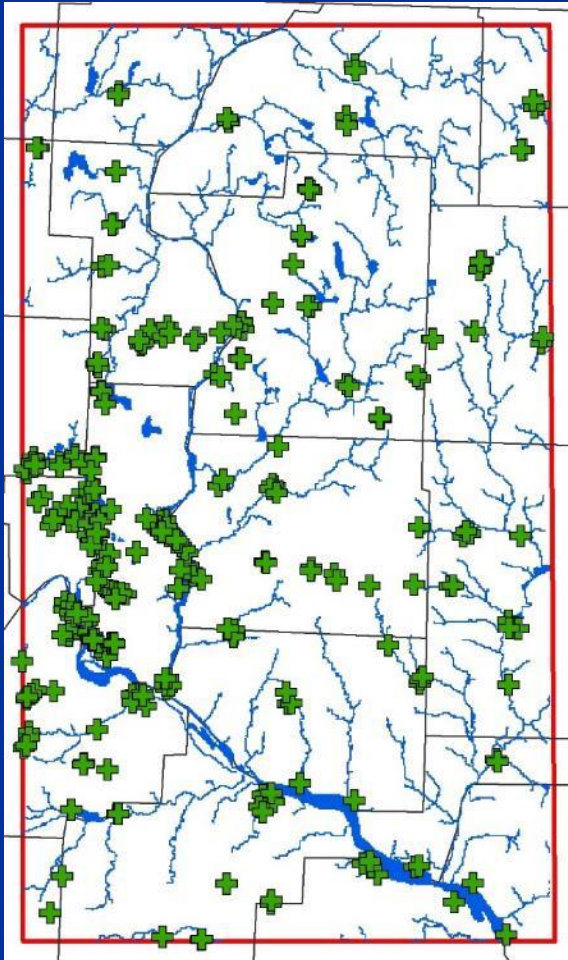
- Construction
  - 4 continuous layers
  - Layer 1 (upper bedrock aquifer) lumps many aquifers and confining units.
  - Sand and gravel (orange & red) aquifers are simulated where bedrock is absent (“windows” along major rivers)
  - Inactive where the aquifer is absent and replaced by crystalline rock (“trap rock”)
  - Faults: uplift, permeability change, barrier where crystalline rock is adjacent to sandstone in layer 4
- Sources and sinks
  - Recharge (uniform)
  - Rivers
  - Pumping wells (average from 1994 – 2004)



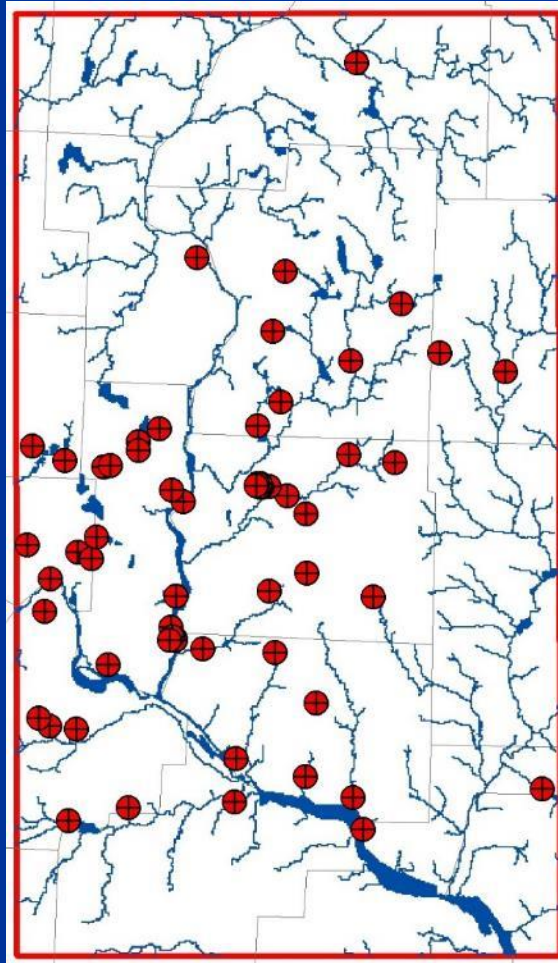


# Tri-county Regional Model

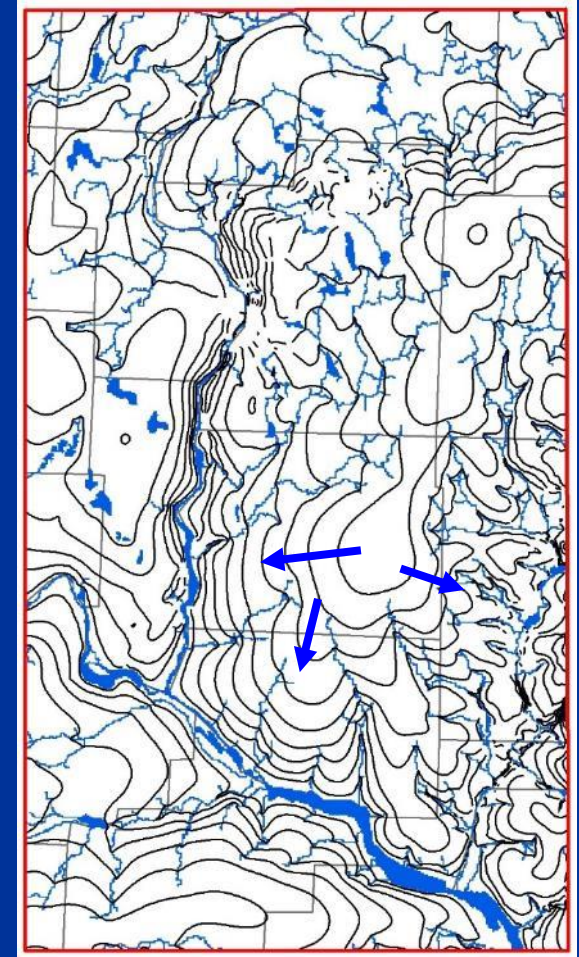
Sources and sinks of water  
(recharge, rivers & wells)



Compare to measurements  
(monitoring wells)







Simulate water levels  
and flow (layer 1)

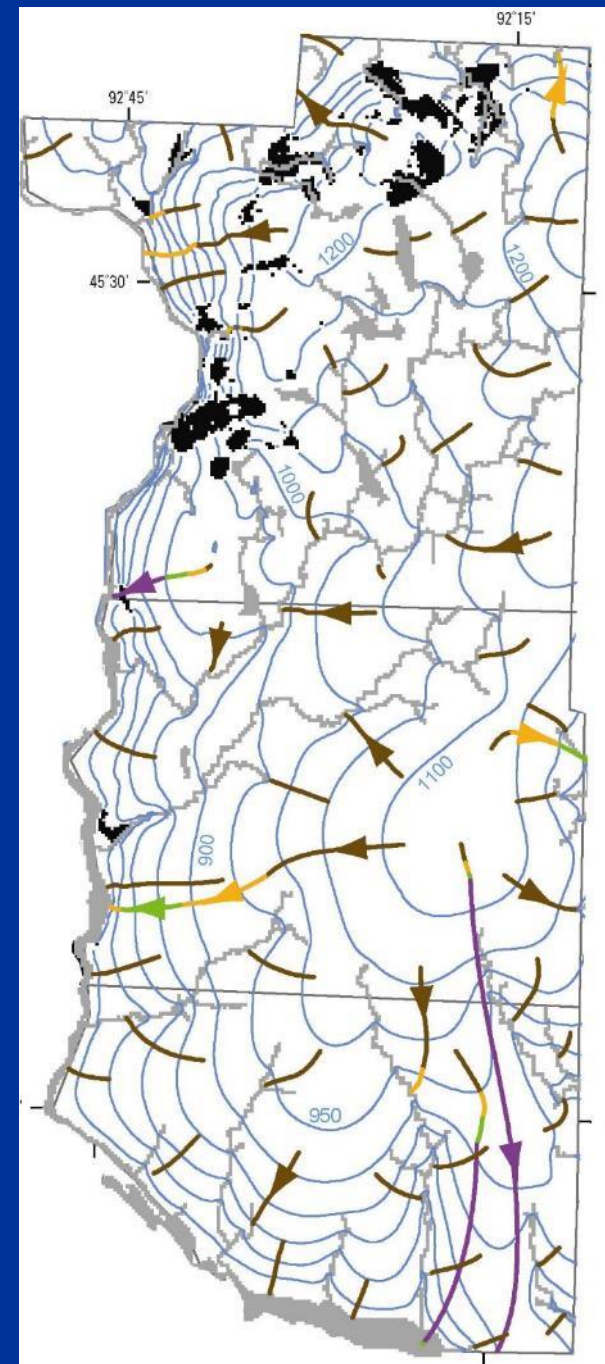
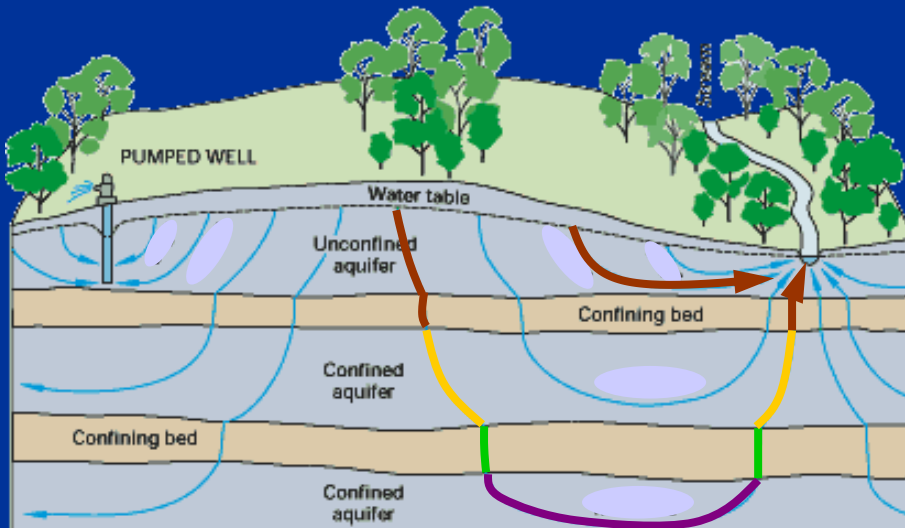




# Flow Directions

Water moving through:

-  Layer 1
-  Layer 2
-  Layer 3
-  Layer 4

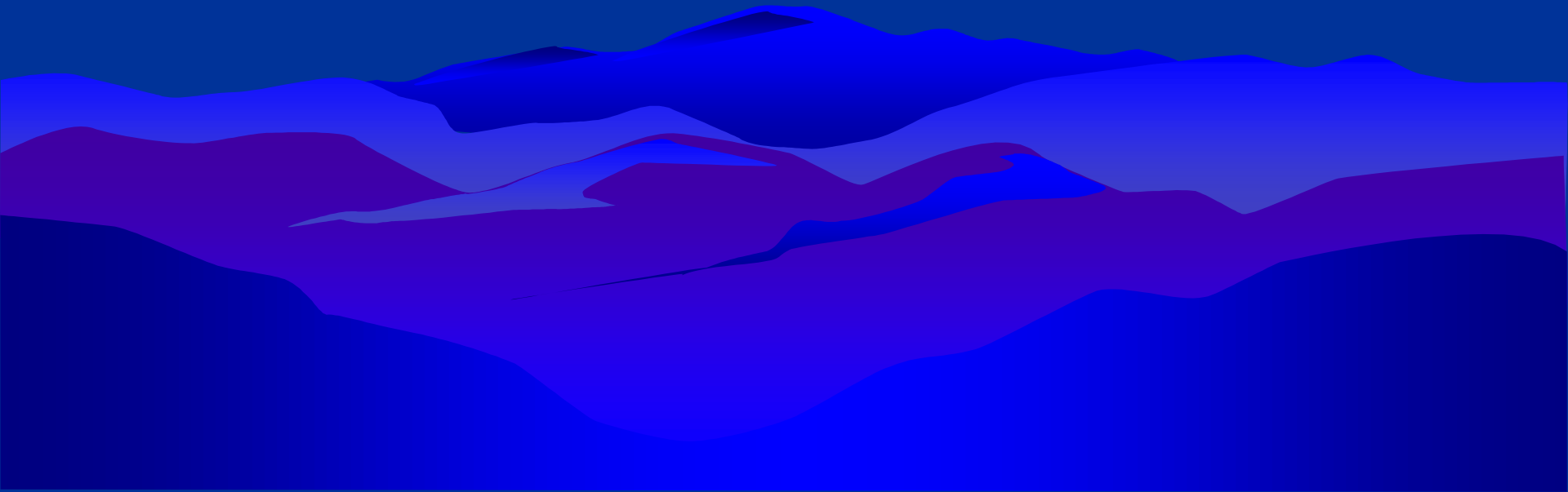


# Ground Water Budget

	Ground water In	Ground water Out
Recharge	82%	0%
Rivers	15%	85%
Wells	0%	1%
County boundaries	4%	14%

What else could be learned?

Can existing tools help with  
karst aquifer problems?



# Differences between porous media and karst

- **Porous media** (sandstone, sand & gravel):
  - Laminar (smooth) flow through whole aquifer thickness
  - Traditional equations describe flow and transport velocity
  - Understanding is often transferable from one site to the next for each aquifer
- **Fractured rock and karst** (limestone, dolomite):
  - Flow through discrete fractures and conduits dominates
  - Turbulent flow and transport velocities can require unique investigation and higher uncertainties
  - Geometries and connections among discrete conduits can differ among individual sites

# When can karst be approximated with a groundwater model?

What is the scale?

Is it a water availability question, or transport question?

Example:

- “How much will pumping deplete baseflow in this stream?”
  - Water availability question (capture)
  - Large pumping rate = regional effect  
(porous media assumptions become better with increasing scales)

Answer will depend on the pumping rate & distance

# When can karst be approximated with a groundwater model?

What is the scale?

Is it a water availability question, or transport question?

Example:

- “Where does water for this well (or stream or lake) come from ?”
  - Transport question
  - Area contributing recharge

Answer will depend on the flow directions and pumping rate

# When can karst be approximated with a groundwater model?

What is the scale?

Is it a water availability question, or transport question?

Example:

- “Where will this contaminant go, and when will it arrive at a specific location?”
  - Transport question
  - Highly site specific

Answer will depend on the flow direction and velocity (degree of karst)...and the contaminant

# When can karst be approximated with a groundwater model?

What is the scale?

Is it a water availability question, or transport question?

The quality of each answer is dependent upon:

- Scale
- Available data & tools
- Required level of precision (safety factor)
- ...& type and precision of the question



## The image shows the front cover of a report. At the top left is the USGS logo, which includes a stylized mountain and the text 'USGS' and 'United States Geological Survey'. To the right of the logo, the title 'Simulation of the Groundwater Flow System in Pierce, Polk, and St. Croix Counties, Wisconsin' is printed in a serif font. Below the title, the author 'Robert E. Anderson, Robert L. Fournier, and R. L. Zecher' is listed. The central part of the cover features a 3D perspective view of a topographic map of a region, with colors representing elevation. The map is tilted, showing a valley and surrounding hills. At the bottom of the cover, the text 'Scientific Investigations Report 2002-1224-B' is printed. In the bottom left corner, there is a small block of text: 'U.S. Department of the Interior U.S. Geological Survey'.

The regional and demonstration groundwater-flow models could be enhanced with additional hydrologic and geologic investigations, data collection and interpretation, and the use of additional MODFLOW options and packages. As new data become available, the models could be updated and recalibrated. The following is a list of investigative tasks, data-collection needs, and MODFLOW options that could increase the utility of the groundwater-flow models.

2. The hydraulic relations between the St. Croix, Mississippi, and Chippewa Rivers and the groundwater system are not fully understood. Specifically, the extent of "windows" in the shale-rich Eau Claire Formation below the rivers is approximated in the regional model by interpolation of stratigraphic contacts in well logs and geologic mapping in adjacent Minnesota counties. Additional geologic and/or geophysical mapping within the St. Croix, Mississippi, and Chippewa River Valleys could improve understanding of groundwater/surface-water interaction near these important regional water bodies and could improve understanding of groundwater-flow patterns and drawdown in the deep aquifers.
  3. The hydraulic effects of faulting are not fully understood in the three counties. For example, in the present simulation, faults are assumed to enhance vertical permeability and diminish horizontal permeability relative to the hydrostratigraphic unit the fault intersects. Although hydraulic properties of the faults had only moderate sensitivity (fig. 15) for the regional model calibration, faults may have substantial influence on local flow patterns and drawdown. Local hydraulic studies of flow through areas with faulting (for example, by use of nested wells, pumping tests, tracers, or geologic core samples) would help to evaluate the degree to which faults influence local groundwater flow.
  4. Flow through local karst aquifers, particularly in central St. Croix and Pierce Counties, is not well simulated in the regional model. Karst aquifers in this study have been lumped with porous sedimentary aquifers, and flow through karst aquifers has been approximated by use of porous-media assumptions. Work by Runkel and others (2003), LePain and others (2005), Tipping and others (2006), and Cobb (2007) provides a basis for advancing the understanding of local groundwater flow in karst aquifers in the counties, and these authors' publications include suggestions for better characterizing these poorly understood areas.
  5. Springs in the river valleys are not simulated explicitly because of the regional consolidation of the upper 200 ft of the aquifer. Explicit simulation of spring flow in the future, but do geologic and hydrologic information (Cobb, 2007) identified an apparent topographic position. Group. An improved understanding of temporal sources of water to the aquifer and additional field investigation.
  6. The distribution and rate of potential to alter recharge in the three counties. Recharge of water to aquifers that sum
- (table 4). A understanding of recharge distribution would assist water-resource managers in evaluation of the effectiveness of mitigation practices designed to protect or enhance recharge in local areas. Tools now exist that are designed to estimate patterns and rates of recharge on the basis of physical processes and the properties and patterns of soils, rocks, precipitation, evaporation, and streamflows in an area (S.M. Westenbroek, U.S. Geological Survey, written commun., 2008).
7. To increase the utility of the regional model, several features could be added. Climatic variations, such as drought and significant recharge events, can be simulated if the model is run in transient mode, as demonstrated with the Polk County inset model. An optimization code, such as the MODFLOW module GWM (Alhalaf and others, 2005), which helps select the optimum or "best" pumping schemes for a given objective (for example, maintaining surface-water flows while increasing groundwater withdrawal), could be coupled to the groundwater-flow model to enhance the model as a tool to guide location of future wells and developments. An optimization model could be used to choose well locations so that future pumping would have a minimal adverse effect on streamflow and wetlands but still meet increased water needs associated with population growth in the three counties.
  8. The three inset models were constructed for demonstration purposes only. However, these models could be enhanced to address specific questions through the collection or compilation of additional hydrologic data and by calibration of the models to address the stated purpose. Simulation of groundwater flow through karst aquifers in the St. Croix County model would most likely be improved with data from investigations described in item 4 above. Simulation of groundwater/lake-water interaction near Twin Lakes would be improved with data from a focused field investigation of local hydraulic gradients and water-budget components for the lake. Delineation of groundwater-contributing areas in Pierce County could be improved with measurements of base flow along Big River and from evaluations of how uncertainty in model
- <https://pubs.er.usgs.gov/publication/s20095056>

<https://pubs.er.usgs.gov/publication/sir20095056>

# Another Useful Reference:

## **Hydrostratigraphy of West-Central Wisconsin: A new approach to groundwater management**

**Final Report to the University of Wisconsin Water Resources Institute**

**Prepared by**

David L. LePain  
Geologist

Kenneth R. Bradbury  
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University of Wisconsin-Extension

[http://wri.wisc.edu/Downloads/Projects/Final\\_WR04R006.pdf](http://wri.wisc.edu/Downloads/Projects/Final_WR04R006.pdf)

Questions?

